

SECTION 16- CRUX UNITS

16.1 CRUX Units Description and Features

This section is intended to familiarize the user with the new chest deflection measurement system which GESAC has developed for the THOR dummy. This instrumentation is known as the CRUX System - Compact Rotary Unit. Four CRUX units are used in the thorax of the THOR dummy to measure the three-dimensional, time-wise deflection of four distinct points of the rib cage. This measurement system is basically a two-bar linkage which features three measured degrees of freedom to provide a complete three-dimensional measurement at the end of the unit. The unit is attached to the rib of the dummy with a universal joint, which also provides three additional mechanical degrees of freedom. The measurement of the position of the unit is made with respect to the base and the center of the universal joint. **Figure 16.1** shows a detail drawing of the various parts of a CRUX unit for reference. The CRUX base is attached to the thoracic instrumentation bracket which bolts to the spine assembly. The U-joint assembly is mounted to the front of the thorax assembly and attaches to the bib and ribs.

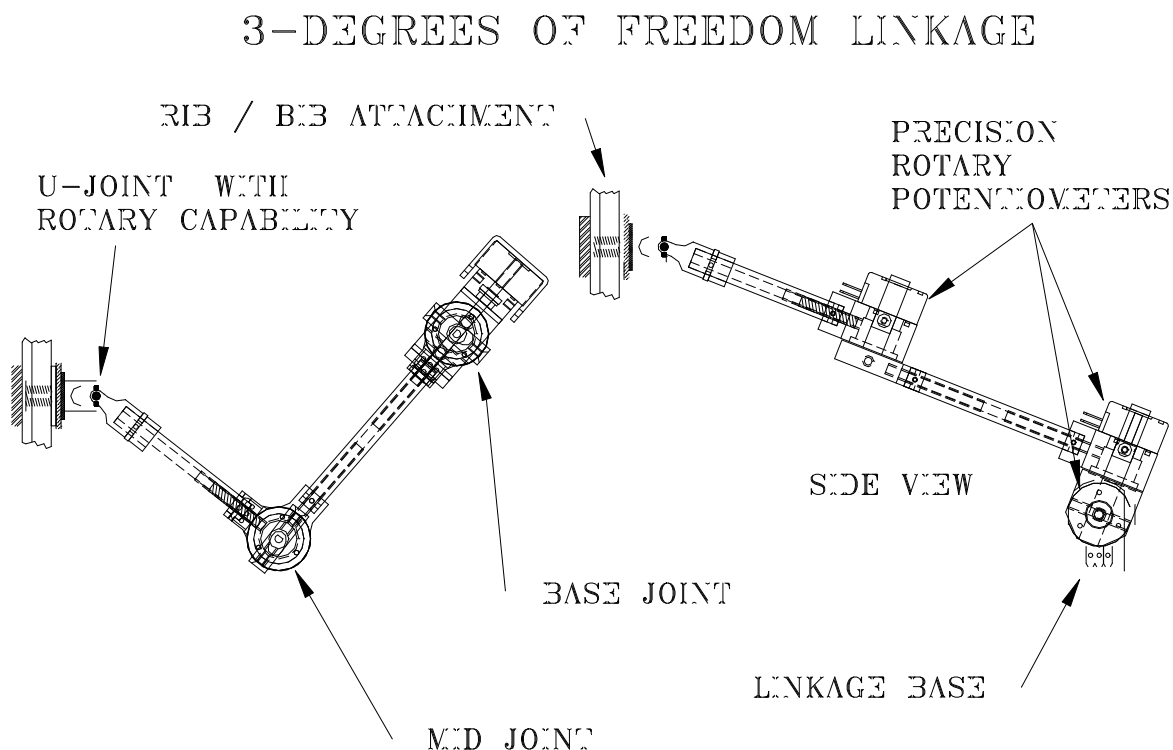


Figure 16.1- CRUX assembly

The CRUX system uses three precision rotary potentiometers to measure the position of the various link-arms. These potentiometers feature 0.25% linearity and 315 degrees of allowable rotation. The potentiometers have stops which prevent full rotation, thus it is necessary to set up the units for either the right- or left-hand side of the thorax.

WARNING: It is possible to damage the potentiometers of the CRUX unit with improper handling. Each unit is unique and is designed for a very specific range of motion. If the units are removed from the dummy, **the arms should be taped in its installation position (as if it were installed in the dummy)** so that the linkages cannot rotate to prevent over ranging the potentiometers.

These units have been designed and calibrated for a 10.0 V DC excitation. (Note: If a different excitation voltage is required for a specific testing application, contact the manufacturer and request the appropriate units. It is possible to provide custom calibrated units which can be calibrated for any DC excitation between five and twelve volts to allow for variations in excitation voltage at different testing facilities. It is necessary to match the excitation voltage used during testing with the excitation voltage used during calibration.)

The CRUX units are calibrated prior to insertion within the dummy thorax. Once the calibration has been performed, the unit may be inserted into the thorax and tested up to 25 times before recalibrating. (Note: If damage or suspicious output is discovered at any time during the testing, the units should be recalibrated.) During the calibration procedure, the output voltage from each of the three potentiometers is measured and recorded for various angular orientations of the unit. This calibration information is used to define the calibration and setup variables in the input parameter file to be used with the THORTEST software program. During impact testing, the output voltages from each of the three potentiometers are recorded with a data acquisition system. This data is processed post-test using the THORTEST program to convert the output voltages into actual three-dimensional coordinates (X, Y, Z displacement). Thus the initial, dynamic, and final positions of the unit can be determined directly from the potentiometer output voltage signals.

The CRUX units attach to the mounting plate of the upper abdomen assembly and feature a highly modular design. They can be inserted and removed from the thorax easily, with minimal disassembly of the spine or ribcage. Additional information in the CRUX assembly and disassembly can be found in Section 7 - Thorax and 9 - Upper Abdomen. In addition, the units themselves are modular, making it very simple to replace any parts that are damaged during testing.

16.2 Assembling CRUX Units

16.2.1 Parts List

The parts list and all quantities for the CRUX assembly are listed in Appendix I - Bill of Materials under the CRUX subsection. Refer to drawing T1CXM000 in the THOR drawing set for a detailed mechanical assembly drawing. **Figure 16.2** is a photograph of the exploded CRUX units and mounting hardware.

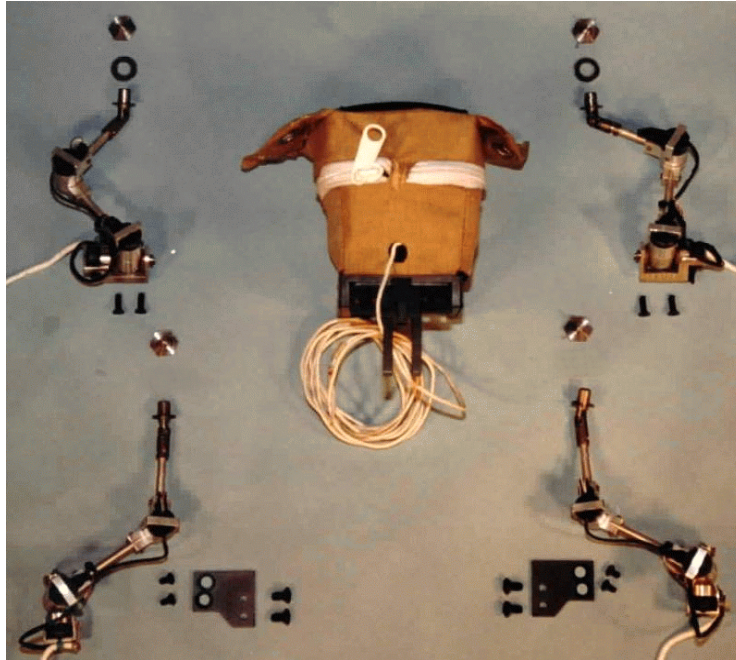


Figure 16.2- Exploded CRUX assembly

16.2.2 Attaching CRUX Units to the Upper Abdomen Assembly

The following procedure is a step-by-step description of how to mount the four CRUX units to the completed upper abdomen assembly. After the units have been attached to the thoracic instrumentation bracket, the bracket assembly will be ready for insertion into the THOR dummy. The numbers noted in () refer to a specific drawing / part number for each part. The numbers noted in the { } indicate the hex wrench size required to perform that assembly. All bolts should be tightened to the torque specifications provided in Section 2.1.3.

1. Mount the Upper Right CRUX Unit (T1CXM001) onto the top right-side of the thoracic instrumentation bracket on the Upper Abdomen Assembly (T1UAM000) using two #10-24 x 5/8" FHSCS {1/8}, as shown in **Figure 16.3**. The base pot should be oriented to the right, away from the center of the bracket assembly as shown.

NOTE: The orientation of these units is essential, they must be positioned exactly as shown in the supplied photographs.



Figure 16.3- Upper Right CRUX installed

2. Mount the Upper Left CRUX unit (T1CXM002) onto the top left-side of the thoracic instrumentation bracket using two #10-24 x 5/8" FSHCS {1/8}, as shown in **Figure 16.4**. The base potentiometer should be oriented to the left, away from the center of the bracket assembly as shown.

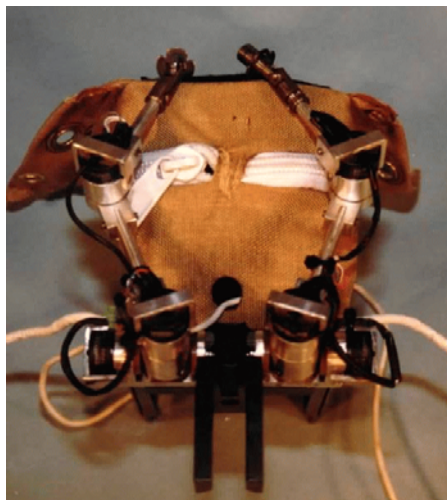


Figure 16.4- Upper Left CRUX installed

3. Mount the Lower Right CRUX Unit (T1CXM003) to the Lower Right CRUX Mounting Bracket (T1CXM401) using two #10-24 x 3/8" FSHCS {1/8}, as shown in **Figure 16.5**. The lower right CRUX mounting bracket is stamped with the letter R. When this piece is held so the stamp is readable, the piece is oriented correctly. The CRUX base should be mounted to the stamped side of the bracket. The flat heat bolts should fit into the countersunk holes in the mounting bracket. The base pot of the CRUX unit should be oriented so it points in the upward direction.

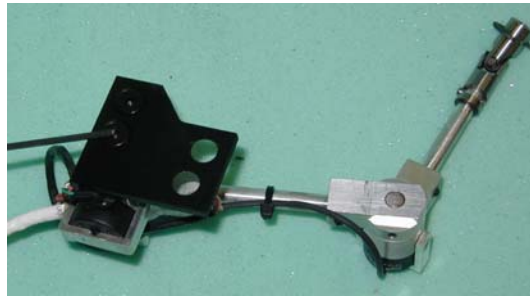


Figure 16.5- Lower Right Mounting Plate attached to Lower Right CRUX unit

4. Mount the Lower Left CRUX Unit (T1CXM004) to the Lower Left CRUX Mounting Bracket (T1CXM400) using two #10-24 x 3/8" FSHCS {1/8}, as shown in **Figure 16.6**. The lower left CRUX mounting bracket is stamped with the letter "L". When this piece is held so the stamp is readable, the piece is oriented correctly. The CRUX base should be mounted to the stamped side of the bracket. The flat heat bolts should fit into the countersunk holes in the mounting bracket. The base pot of the CRUX unit should be oriented so it points in the upward direction.

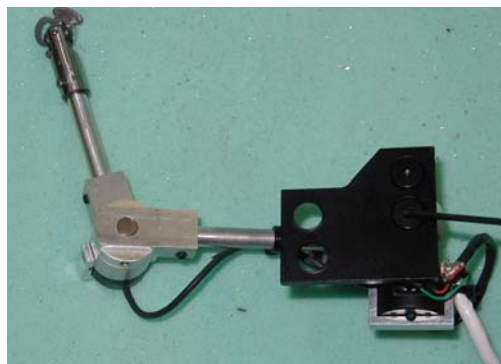


Figure 16.6- Lower Left Mounting Plate attached to Lower Left CRUX unit

5. Position the lower right CRUX / mounting bracket assembly on the right side of the upper abdomen assembly. Mount this bracket assembly using two 1/4-20 x 1/2" FHSCS {5/32}, as shown in **Figure 16.7**. The bolts should pass through the countersunk holes in the CRUX mounting bracket, through the upper abdomen internal mounting plate and into the upper abdomen spinal mounting bracket.



Figure 16.7- Lower Right CRUX installed

6. Position the lower left CRUX / mounting bracket assembly on the left side of the thoracic instrumentation bracket. Mount this bracket assembly using two 1/4-20 x 1/2" FHSCS {5/32}, as shown in **Figure 16.8**. The bolts should pass through the countersunk holes in the CRUX mounting bracket, through the upper abdomen internal mounting plate and into the upper abdomen spinal mounting bracket.



Figure 16.8- Lower Left CRUX installed

7. Secure the CRUX wires to the upper abdomen assembly with a 1/4-20 x 1/2" BHSCS {5/32} and a 1/4" nylon cable clamp on each side, as shown in **Figure 16.9**. These bolts are fastened through the top mounting hole of the upper abdomen assembly.

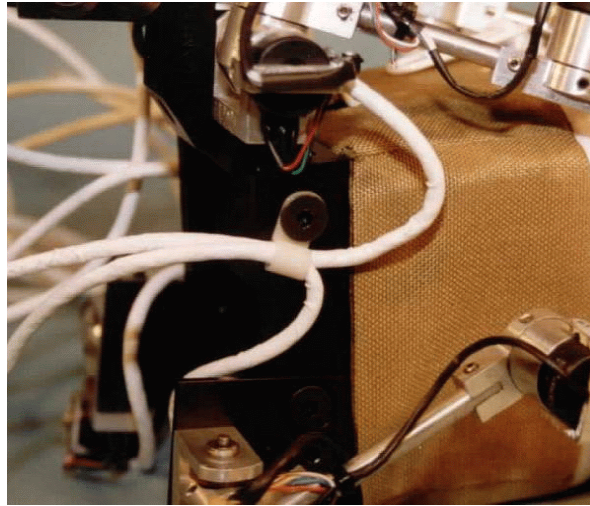


Figure 16.9- Wire strain relief location

16.2.3 Installing the Completed CRUX Bracket Assembly into the THOR Dummy

The following procedure is a step-by-step description of how to install the completed CRUX upper abdomen / CRUX assembly into the THOR dummy. The numbers noted in { } indicated the Hex wrench size required to perform that assembly step. All of the bolts in this assembly should be tightened securely.

1. Position the two tabs of the upper abdomen assembly over the lower thoracic spine weldment, and align the holes as indicated in **Figure 16.10**.

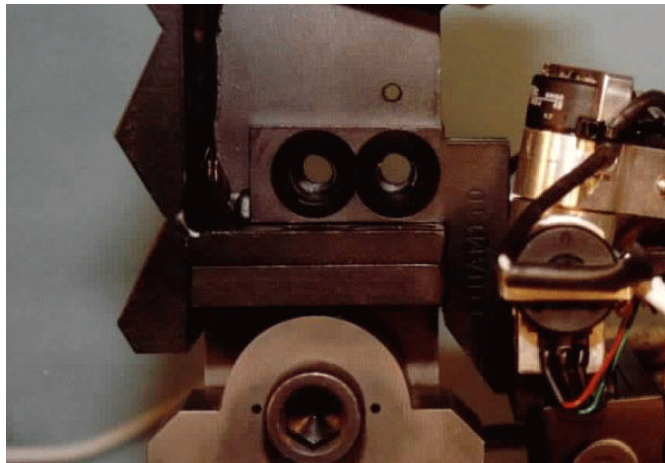


Figure 16.10- Proper hole alignment

WARNING: The bracket assembly must be inserted very carefully into the dummy to avoid damage to the instrumentation wiring. The lower thoracic tilt sensor wire is especially susceptible to damage during this procedure.

2. Secure the spinal mounting bracket of the upper abdomen assembly to the lower thoracic spine weldment placing two 5/16-18 x 1" FHSCS {3/16} into the two mounting holes in the spinal mounting bracket arms from the right side, as shown in **Figure 16.11**. The bolts should be inserted from the right hand side of the dummy and pass through one tab of the thoracic instrumentation bracket, through the holes in the lower thoracic spine weldment and thread into the other tab of the thoracic instrumentation bracket.

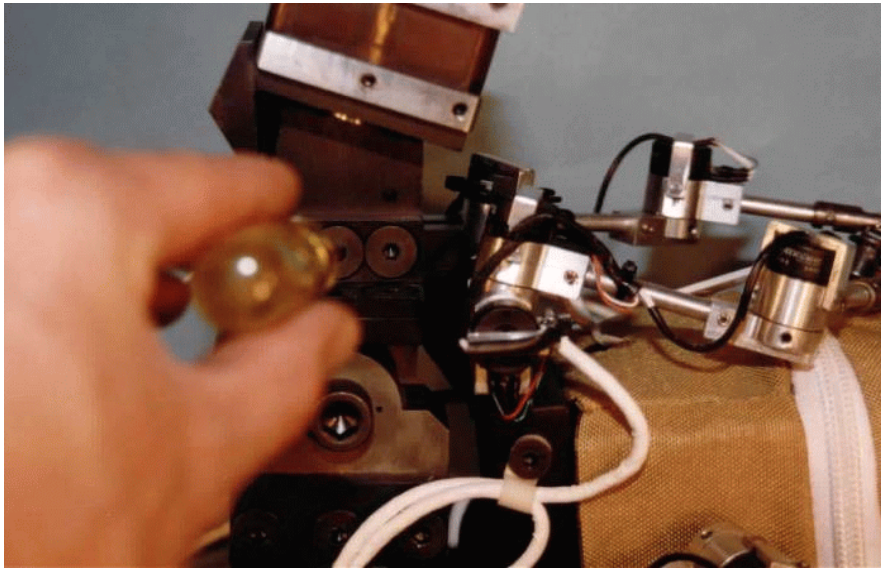


Figure 16.11- Upper Abdomen mounted to Spine

3. Continue by following the procedure outlined in Section 7.2.2 - Assembling the Thorax.

16.3 Adjusting the CRUX Units

The only adjustment required for the CRUX units is to ensure that the U-joint has been positioned in the middle of its rotational range of motion during the installation. The U-joint was designed for limited rotation on the end of the CRUX arm, and it should be set to the middle of this rotation range during installation, as shown in **Figure 16.12**. The position of the U-joint should be verified with a visual inspection.

NOTE: A simple way of setting the U-joint in the middle of its range of motion is to tighten the CRUX rib connecting bolt using a 3/4" wrench until contact is felt. The U-joint will be at one end of its range of motion. Turn the rib bolt counterclockwise slightly, causing the U-joint to rotate on the CRUX arm until the U-joint is centered. The position of the U-joint must be verified visually.

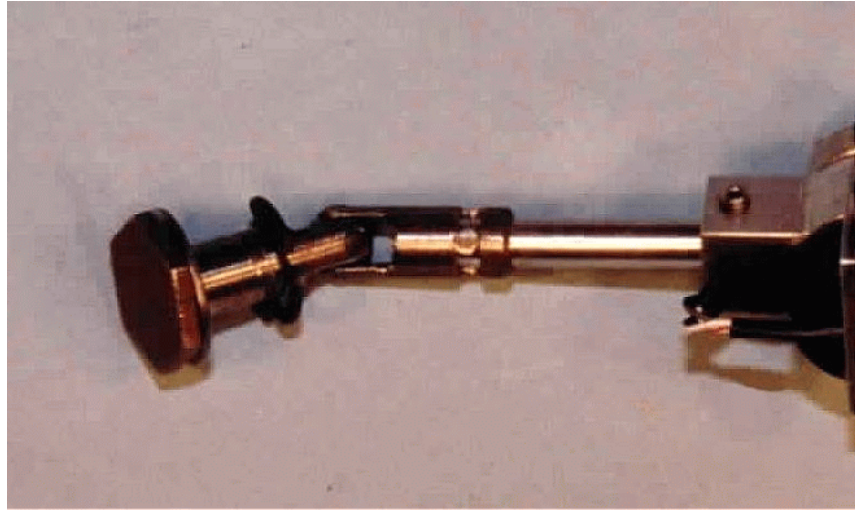


Figure 16.12- U-Joint centered in its range of motion

16.4 Electrical Connections and Requirements

16.4.1 Wire Routing

The wire routing for the four CRUX units is very critical since the wires must be secured away from any moving parts within the thorax assembly. The proper routing for the instrumentation wires from each unit is described below. The wire routing is also depicted in **Figures 16.13** and **16.14**.

Upper Right CRUX Unit: This wire is bundled with the lower right CRUX wire and is secured to the right side of the upper abdomen plate. The wire from this unit must run down along the rear of the spine assembly on the right-hand side. This wire must exit below rib #7 to join the wire bundle.

Upper Left CRUX Unit: This wire is bundled with the lower left CRUX, the mid-sternal uniaxial accelerometer, and the upper abdomen uniaxial accelerometer, and is secured to the left side of the upper abdomen plate. The wire from this unit must run down along the rear of the spine assembly on the left-hand side. This wire must exit below rib #7 to join the wire bundle.

Lower Right CRUX Unit: This wire is bundled with the upper right CRUX wire and is secured to the right side of the upper abdomen plate. The wire from this unit should run parallel to the wire from the upper right unit and exit in the same location.

Lower Left CRUX Unit: This wire is bundled with the upper left CRUX, the mid-sternal uniaxial accelerometer, and the upper abdomen uniaxial accelerometer, and is secured to the left side of the upper abdomen plate. The wire from this unit should run parallel to the wire from the upper right unit and exit in the same location.

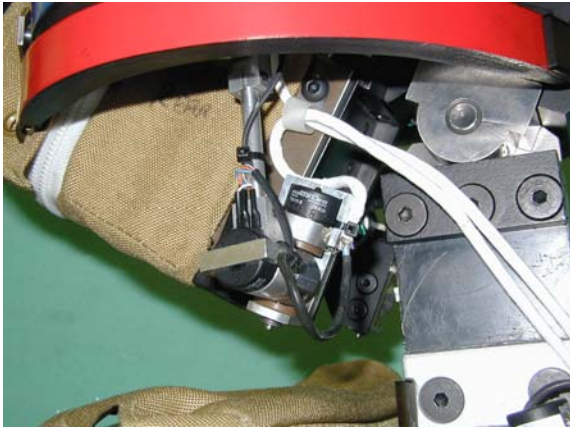


Figure 16.13- Left side wire routing



Figure 16.14- Right side wire routing

16.4.2 CRUX Unit Electrical Connection

Each CRUX unit is wired by the manufacturer with a 15' multi-conductor instrumentation wire. Depending on the dummy application, this wire may be terminated with a set of three high quality, four-pin LEMO connectors fully shielded, for the dummies that are on lease. The dummies that are commercially sold usually have a bare wire end.

On the leased dummies, the wires have been broken out into three bundles and the connector wires have wire color coding as described in Section 15 - Instrumentation and Wiring. **Table 16.1** shows the wiring code for the commercially sold products.

Table 16.1

Wire Color	Function
Red	Pot #1: +Excitation
Black	Pot #1: Ground
Green	Pot #1: Output
Orange	Pot #2: +Excitation
Black Stripe	Pot #2: Ground
Blue	Pot #2: Output
Red Stripe	Pot #3: +Excitation
Gray	Pot #3: Ground
White	Pot #3: Output

The potentiometers from the CRUX units are designed to be measured as a referenced single-ended channel configuration in which the + Signal lead is connected to a HI input channel of the data acquisition system. The data acquisition system is then configured as a referenced single-ended input to measure the voltage difference between the HI channel input and the ground reference. The CRUX multi-conductor wire is shielded to prevent cross-talk with other instrumentation. The recommended excitation voltage for the CRUX units is 10.00 V DC. Under normal operation conditions, the output signal from any of the three potentiometers should be between 0 and 10 volts DC. A simple voltage check may be used to determine if the potentiometers are outputting a voltage in the expected range of 0 to 10 V DC.

WARNING: The output voltage from the rotary potentiometers should never actually read 0.0 or 10.0 volts. Readings of exactly 0.0 or 10.0 indicate the potential existence of a short in the signal wire to either ground or + Excitation.

The CRUX units are designed to be removed and assembled as a complete unit. The disassembly of the individual components which make up a complete CRUX assembly is beyond the scope of this manual. The electrical connections and wiring for the CRUX units are performed during the assembly of the unit by the manufacturer. It is **HIGHLY RECOMMENDED** that the CRUX units experiencing electrical problems be returned to the manufacturer for repair. The following description of the CRUX unit wiring is provided as a reference and guide for test facilities wishing to attempt repair of these units themselves.

If a wire from a potentiometer should break or become disconnected, it is necessary to clean the contact and resolder the wire. (Note: A small piece of heat shrink tubing should be placed over the wire before reconnecting so the joint may be sealed after the repair is finished.) The correct orientation of the wires on the units can be obtained by holding the potentiometer so the top is facing upward and the side with the electrical contacts is visible. The contact on the right (as viewed) is ground, the contact on the left (as viewed) is positive excitation and the central contact is the output signal. This is shown in **Figure 16.15** below. Once the broken wire has been repaired, the heat shrink tubing should be positioned over the soldered joint, then contact and heated with a hot-air gun to secure it in place.

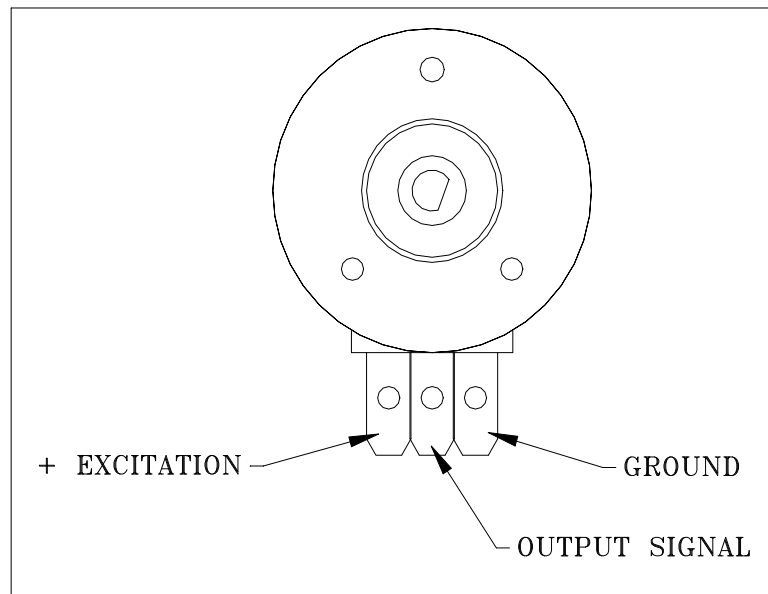


Figure 16.15- Potentiometer contact description

16.5 CRUX Measurement System Calibration

Prior to installing the CRUX units into the thorax assembly, each unit must be calibrated to determine the output voltage for various angular orientations. The calibration of these units is most easily performed on the CRUX Calibration Fixture (T1CME100) which is available for purchase from the manufacturer. This fixture was designed to accurately position the CRUX unit into several predefined orientations. The voltage output from each of the potentiometers is measured and recorded for each position to provide an accurate calibration. These voltage outputs are correlated with the known angles of the calibration plate and the calibration factor (mV/deg) and initial offset are calculated for use in the THORTEST. Each CRUX unit is calibrated by the manufacturer upon initial assembly, and may be returned to the manufacturer for recalibration at any time. It is recommended that the unit be recalibrated after 25 tests have been conducted.

The calibration procedures for the CRUX units are described in the THOR Calibration Manual, which is available from the manufacturer as a separate publication.

NOTE: If at any time during the testing the output of the CRUX units reaches the level of 0.00 (ground) or 10.0 (+excitation), or if the units have physical damage, the units should be removed, inspected, and recalibrated.

16.6 Inspection and Repairs

After a test series has been performed, there are several inspections which may be made to ensure the dummy's integrity has remained intact. Use good engineering judgement to determine the frequency of these inspections; however, the manufacturer recommends a thorough inspection after twenty tests have been performed. Inspection frequency should increase if tests are particularly severe or if unusual data signals are being recorded. Both electrical and mechanical inspections are most easily carried out during a disassembly of the dummy. Disassembly of the CRUX units from the dummy and upper abdomen assembly can be performed by simply reversing the assembly procedure. Some comments are provided below to assist in this process.

16.6.1 Electrical Inspections (Instrumentation Check)

Begin with the visual and tactile inspection of all instrument wires. Wires should be inspected for nicks, cuts, pinch points, and damaged electrical connections which would prevent the signals from being transferred properly to the data acquisition system. The instrument wires should be checked to ensure they are properly strain relieved. A more detailed check of the individual instruments is covered in Section 15- Instrumentation and Wiring.

16.6.2 Mechanical Inspection

The CRUX units will require a visual inspection to determine if they are still functioning properly. This mechanical inspection should also involve a quick check for any loose bolts in the main assembly. Each area of mechanical inspection will be covered in detail below. Please contact the manufacturer regarding questions about items that fail the mechanical inspection.

CRUX Units: The following checklist should be used when inspecting the CRUX units for post-test damage:

- C Check tightness of rib / bib connection bolts and CRUX rib connection bolts
- C Check that U-joints for CRUX units are still positioned in the middle range of their allowable rotation.

In addition, a more detailed inspection can be conducted if the units are removed. (Removal is not recommended unless a problem is suspected.)

1. Inspect the universal joint end to ensure it moves freely and has free rotation about the end of the CRUX shaft. (Note: The rotation is limited by a pin, but the motion should be smooth and require little effort.)

WARNING: The potentiometers feature built in stops to prevent over rotation - do not force the unit past these stops. The potentiometers will have severe damage if the units are rotated past their designed range of motion.

2. Inspect the three joints of the CRUX units to ensure that the motion of the joints is free and smooth. (**Note:** The potentiometers have built in stops that prevent the units from rotating 360 degrees.)
3. Inspect the potentiometers and joints for physical damage which may indicate contact between the CRUX units and another assembly within the thorax.
4. Inspect the two arms of the CRUX units for rotation where they attach to the joints. No rotation should be possible at these connection points. The only allowable rotation occurs at the universal joint.
5. Inspect the two arms of the CRUX units for physical damage. Bent or twisted arms may indicate a problem with the installation or orientation of the unit within the thorax.
6. Inspect the wiring for physical damage including broken connectors, pinched wires, missing insulation, etc.

If damage is found during the inspection of the CRUX units, the damaged unit should be returned to the manufacturer for repair or replacement. Due to the complicated nature of the CRUX units, the disassembly and repair of the individual components of each CRUX are beyond the scope of this manual. Contact the manufacturer's Engineering Department if further disassembly or inspection is required.